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EXPERIMENTAL TESTING OF SHEET GLASS STRENGTH IN LATERAL BENDING

N. V. Kondrat'eva[1]

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The strength parameters of sheet building glass as a structural material intended to absorb mechanical loads are investigated. Experimental data and the situation in the first moments of destruction of large-sized glass sheets under loading is described.

Considering contemporary requirements imposed on buildings and structures, construction glass ought to be considered not only as an enclosing material capable of light transmission, but also as a structural material intended for absorbing mechanical loads.

At present Russia has no regulatory documents prescribing methods for designing mechanical loads on sheet glasses; consequently, architects designing buildings usually decide on glass thickness intuitively or use design methods developed for elastoplastic materials.

In order to estimate the strength of glass used in light-transmitting structures, the Samarastroiispytaniya Testing Center has performed testing of sheet glass in lateral bending under a uniformly distributed load.

Initially we tested samples of size $800 \times 800 \times 4$ mm from different Russian and some foreign manufacturers. To exclude the influence of fixing methods on the stress-deformed state of glass, experimental samples were tested as a plate freely resting on its four sides. A uniformly distributed load was developed by negative air pressure inside the testing chamber, i.e., by vacuum. The design of the chamber is shown in Fig. 1.

Since glass in these studies is considered as a structural material, the testing method is analogous to the method used in testing load-carrying structures. In accordance with this method, a sample is loaded in stages, with an exposure for 10 min at each stage. The readings of measuring instruments are recorded during the exposure (Fig. 2).

In order to estimate the deformed state of samples, in testing we determined the relative deformation of glass in the compressed and tensile zones along the axes x and y passing through the center and along the plate diagonals and also measured the plate deflection taking into account the sinking

[1] Samarstroiispytaniya Testing Center at the Samara State Architectural-Construction University, Samara, Russia.

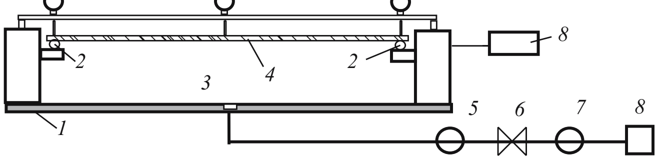

Fig. 1. Design of a plant for testing glass samples under a uniformly distributed load: *1*) airtight chamber made of aluminum alloy; *2*) supports made of elastic tubular rubber along the sample perimeter; *3*) vacuum chamber; *4*) sheet glass sample; *5*) hydraulic pressure gage; *6*) locking valve; *7*) receiver; *8*) vacuum compressor; *9*) clock-like indicators.

Fig. 2. Testing samples of size 800 × 800 mm.

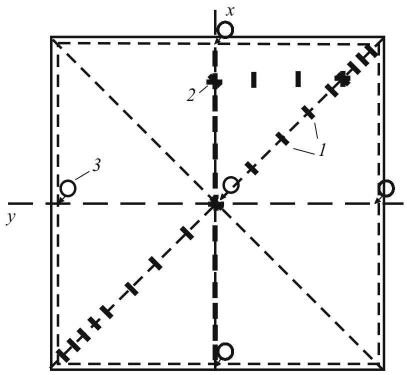

Fig. 3. Layout of instruments in testing sheet glass samples: *1*) film strain-gage resistors with 10-mm base; *2*) rosettes of strain-gage resistors; *3*) indicator heads.

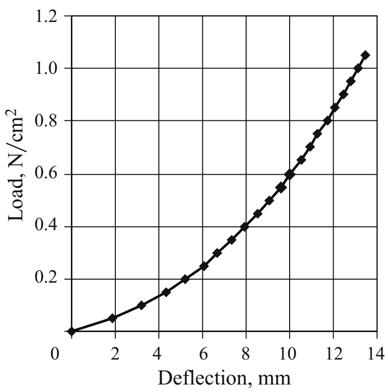

Fig. 4. Deflection of a sample.

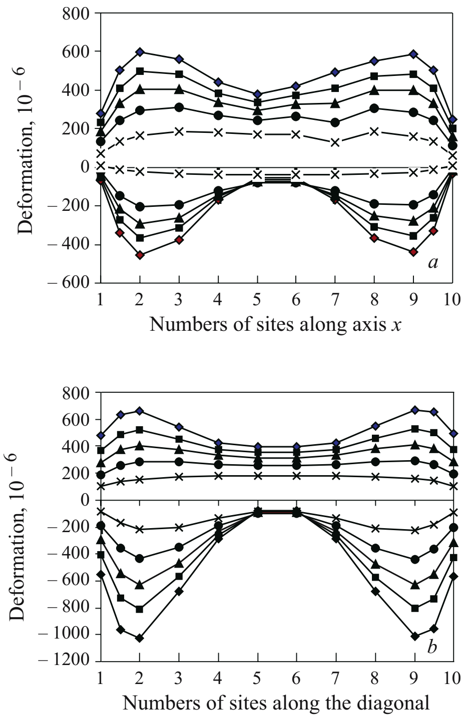

Fig. 5. Deformation of glass in compressed and tensile zones along the axis *x* (*a*) and along the diagonal (*b*) under different levels of loading: ×) $0.2q_{max}$; ●) $0.4q_{max}$; ▲) $0.6q_{max}$; ■) $0.8q_{max}$; ◆) q_{max}.

of the supports. The deformation of glass was determined using film strain-gage resistors.

Glass is a brittle material that does not manifest plastic deformations until the very moment of its destruction. The maximum compressive and tensile deformations of glass are significantly lower than those of other structural materials; therefore, using existing instruments for measuring deformation led to substantial errors. The Testing Center has developed a new strain-gage complex (TK 50) able to measure deformation to an accuracy of 10^{-6} relative deformation units. It has 64 independent channels. In developing this complex, we have used state-of-the-art achievements in the field of strain measurements and thermal compensation of sensors. This complex and the whole measuring process is controlled by means of a Pentium-4 computer. The software of the TK 50 complex is Excel-compatible, which makes it possible to immediately process the measurement data and construct corresponding plots.

The deflection of samples and the sinking of supports was measured using mechanical indicator heads with a scale division of 0.01 mm. The layout of the instruments is shown in Fig. 3.

Analysis of the testing results indicates that the dependence of the deflection of the middle zone of the sample on loading is not rectilinear. At the initial stage of testing, the deflection value is proportional to the load, but this proportionality is disturbed under further loading (Fig. 4). The decreasing increment of the sample deflection at the upper loading levels shows that its rigidity grows in the course of testing. The maximum deflection of a sample of size $800 \times 800 \times 4$ mm was equal to 13 mm, i.e., 1/62 of the side length, with the ratio of the side length to its thickness equal to 1/200. No deflection increment was registered in the sample during its exposure under a load.

Analysis of the deformation variations along the axes *x*, *y*, and the plate diagonals (Fig. 5) indicates that the maximum value of deformation before the fracture of the sample is registered at a distance of about 1/8 of the length along the axes *x* and *y*. At the same time, the relative tensile deformation (600×10^{-6}) on one side of the sample significantly exceeds the compressive deformation on the opposite side (-420×10^{-6}).

The maximum deformation value at the sites located at 1/8 of the diagonal length is registered in compressive deformation (-1000×10^{-6}) compared to the tensile deformation on the same site (610×10^{-6}). Such a state in the glass may be caused by a simultaneous effect of the bending moment and tension acting along the axes *x* and *y* and the bending moment and compression acting perpendicularly to the diagonals (Fig. 6).

The results of processing data from rosette-type strain-gages indicates that the maximum compression and tensile

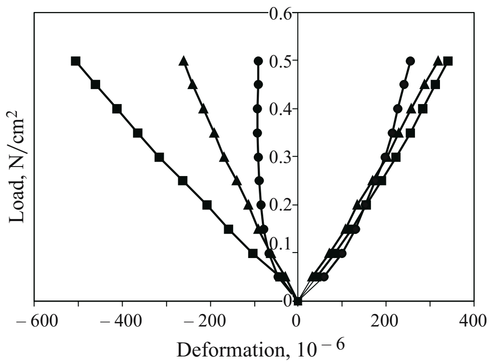

Fig. 6. Dependence of relative deformation of glass on loading: ■) 1/8 diagonal length; ▲) 1/8 length of axis x; ●) in the middle of the sample.

Fig. 7. Fracture of glass in samples.

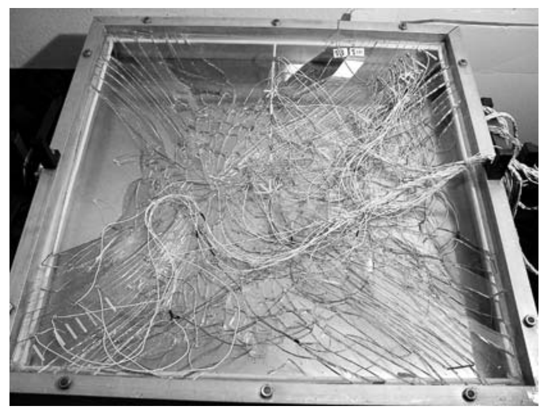

Fig. 8. General view of a sample after testing.

deformations in the corner zones are directed perpendicularly to the diagonal and at an angle of 45° to the plate sides for square plates. The maximum deformations along the axes x and y correspond to the directions of these axes. In the center of the sample, the deformation of the glass surface is actually equal in all directions (Fig. 7).

The dependence of glass deformation on the loading level in the sites located along the axis x and along the diagonal is nearly rectilinear, however, in the middle of the sample this dependence is not rectilinear (Fig. 8).

The destruction of the sample occurs instantly in about 1/30 second. About 80% of samples were destroyed during their exposure between the loading stages.

The decoding of photos obtained in filming in the "still" mode made it possible to identify the place of origin of glass destruction. As a rule, the fracture originates in the corners of samples (Fig. 7).

It can be seen in Fig. 8 that the cracks in the corner zones are directed at 45° with respect to the sample side, and the cracks along the axes x and y are virtually parallel to the sample sides. Some fragments in the middle of each side near the supports in all samples and in the middle zone of some samples remained undestroyed after testing.

In testing samples of size 1200 × 1500 × 4 mm the type of destruction and the maximum deformation zones were similar.

Based on testing 60 glass sheet samples, the following conclusions can be made:

– sheet glass with a ratio of the side length to glass thickness equal to 1/200 in the case of lateral bending behaves as a thin plate;

– the dependence of glass deflection on load is not rectilinear, which points to the growth of the bending rigidity of the plate under an increasing load;

– the maximum deformations on the glass surface are observed not in the middle of the sample, but in the corner zones, at a distance of about 1/8 of the diagonal length;

– bending and compressive deformations arise in the corner zones directed perpendicular to the diagonal, whereas bending and tensile deformations are formed along the axes x and y;

– the destruction of samples occurs instantly, without plastic deformation; however, around 80% samples were destroyed during their exposure under a load.